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TO: Mr. R.A. Grunau
Manager of Safety
Construction and Services Division
H17A13

ELECTRICAL TESTS ON MANLIFT DEVICES: SUMMARY REPORT

S.M. Harvey

1.0 INTRODUCTION

Inspection Report 79418, dated April 2, 1991, and issued by the Ontario Ministry of Labour, restricted the use of movable working platforms (manlift devices) operated by mechanical or electrical power in the vicinity of energised lines or equipment. The platforms were not to be brought closer than minimum distances set out in Section 105(4) of R.R.O. 691/80 or the manufacturer's instructions, whichever is greater, unless specifically designed for the work being performed.

Working distances are governed by a number of different criteria. The Ministry of Labour guidelines Section (105)4 specifies a minimum distance of 6 m (19.7 ft) between work vehicles and live lines with ratings above 250 kV. For lines with ratings from 250 kV to 550 kV, Ontario Hydro Safety Rules (Section 203) specify a limit of approach of 4.58 m (15 ft) for "Earth Augers, Radial Boom and Pole Derricks, A-Frames and Aerial Ladders" operated by qualified personnel. One manufacturer of work platforms specifies a minimum distance of 6.1 m (20 ft) for voltages between 200 kV and 350 kV, 7.62 m (25 ft) for voltages between 350 kV and 500 kV, and 10.67 m (35 ft) for line voltages between 500 kV and 750 kV.

In response to a request from Construction and Services Division, the Electrical Testing and Development Section of Ontario Hydro Research Division arranged a series of tests of manlift devices at a distance of 4.58 m from live conductors energised at voltages representative of those on the 500 kV transmission system. For each test, the electrical environment and selected

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voltages and currents on the devices were measured by the Science Section of the Research Division. The measurements and the observed performance of the manlift devices are described in this report (henceforth, metric distances will be reported to the nearest 0.1 m).

2.0 TEST SUMMARY

2.1 General

One electric over hydraulic device (a "Grove") was tested in the Research Division's High-Voltage Laboratory under a single conductor (height 6.6 m) energised at a voltage of 318 kV (corresponding to a representative line-to-ground voltage on a 500 kV transmission line). Two devices, a "Simon" hydraulic and a "JLG" model 46H electric over hydraulic, were subsequently tested at a lateral distance of 4.6 m, measured to the nearest platform rail, from a single conductor (height 7.6 m) energised to the same voltage at Ontario Hydro's Kleinberg High-Voltage test site. Finally, two additional devices, a "Simon" hydraulic and a "JLG" model 60HA electric over hydraulic, were tested at a lateral distance of 4.6 m from the outside conductor of the C551V three-phase 500-kV low bus at Cherrywood TS. Bus current and phase-to-phase voltage at the time of the tests were, respectively, 475 to 500 A and 518 kV .

2.2 Electrical Environment

Although the conductors at the High-Voltage Laboratory and at Kleinberg were periodically switched on and off potential during the tests, all tests were effectively under "steady-state" conditions. Unperturbed 60-Hz electric fields at 1 m above ground were highest in the High-Voltage Laboratory (estimated at about 12 kV/m) and lowest at the Cherrywood test site (about 7.5 kV/m). Conversely, only the Cherrywood site had significant 60-Hz magnetic fields, about 10 μT, due to load currents on the energised conductors. The corona field strength was quite high, but not measured, in the High-Voltage Laboratory. The corona field at the Kleinberg site, measured at ground level and at a frequency of 1 MHz, was still high at 600 μV/m/kHz due to the use of a single small-diameter conductor. The corona field at Cherrywood TS was about ten times lower.

2.3 Ground Currents

The 60-Hz current flowing in the safety grounding conductor (due to capacitive induction) is dependent on the height of the platform and on the amount of metal exposed to the energised line. Test results are summarized in Table I.

TABLE I

Grounding Currents (in mA) as a Function of Platform Height

Platform Height (m/ft)	Kleinberg		Cherrywood	
	Unit 1	Unit 2	Unit 1	Unit 2
minimum	1.6	1.8	1.0	1.0
3/10	-	2.4	1.3	1.5
6.1/20	3.4	3.5	2.1	2.4
9.1/30	4.6	4.1	2.4	2.7
12.2/40	6.0	5.4	3.0	3.0
15.2/50	6.2	-	3.3	3.3

A contact test was performed with the "Simon" unit at Cherrywood TS, by electrically connecting the platform to the midpoint of a grounded bus adjacent to the energised bus. This test produced a ground current of 20.2 A.

2.4 Selected Voltages and Currents

Voltages produced on the control wiring of electric over hydraulic devices by electrostatic coupling depend on the platform height and on the individual conductor configuration. Highest voltages are expected to occur on conductors that are isolated at each end by open switches and that are exposed along the length of the platform extension.

Induced voltages were measured on the six terminals of the PLATFORM/GROUND select switch on each of the two electric over hydraulic units, with the platform at a height of 6.1 m. The results are summarized in Table II.

TABLE II

60-Hz Voltages (in V) on PLATFORM/GROUND Switch Terminals

Terminal	Kleinberg		Cherrywood	
	Switch Position		Switch Position	
	GROUND	PLATFORM	GROUND	PLATFORM
A	9.8	0.019	4.8	4.6
B	9.8	0.022	4.7	4.6
C	0.056	0.027	0.040	<0.001*
D	0.035	0.020	0.040	<0.001*
E	0.050	0.027	0.039	<0.001*
F	0.049	0.022	0.039	<0.001*

* measurements so marked were made improperly (the tester's body capacitance or conductance influenced the result)

Electrical Schematics for the "JLG" model 60HA confirm that wires connected to terminals A and B are part of the platform wiring. The short-circuit current available on these conductors is very low (less than 200 μA).

2.5 Equipment Performance

No malfunction of the hydraulic or the electric over hydraulic manlifts was observed during the tests.

3.0 DETAILED TEST DATA

Full details of the tests performed at the High-Voltage Laboratory and at the Kleinberg site are contained in a preliminary report prepared for Construction and Services Division, and included with this report as Appendix A. Supplementary details of the tests performed at Cherrywood TS are provided in Appendix B.

4.0 CONCLUSIONS

Five different movable work platforms, or manlift devices, have been tested at a distance of 4.6 m (15 ft.) from conductors that are energised at voltages representative of 500 kV transmission lines. Two of the devices were fully hydraulic, and three were electric over hydraulic.

Capacitively-induced ground currents ranged from 6.2 mA at 4.6 m from a single conductor energised at a line-to-ground voltage of 318 kV, to 3.3 mA at 4.6 m from a load-carrying three-phase 500-kV substation bus. In comparison, the ground current due to contact with a grounded bus was up to 20.2 A. Electrostatically coupled voltages on isolated ground to platform wires were up to 9.8 V and 4.8 V, respectively, under the same conditions. However, the 60-Hz current that could be supplied by these wires was in the microampere range.

The test conditions had no effect on the operation of the manlift devices under test.

Approved by:

A.F. Baljet
Manager
Electrical Research Department

Submitted by:

S.M. Harvey
Senior Physicist
Science Section
Electrical Research Department

Appendix A

ontario hydro
research division

TO: R.A. Grunau
Manager of Safety
Construction and Services Division
H17A13

ELECTRICAL TESTS ON MANLIFT DEVICES

S.M. Harvey

1. INTRODUCTION

In response to Ontario Ministry of Labour Inspection Report No. 79418 (attachment A), arrangements were made by the Electrical Testing and Development Section of Ontario Hydro Research Division to test three different movable working platforms (manlift devices) in proximity to conductors energised at transmission line voltages. The test conditions and the results of the tests are described in this report.

2. TESTS PERFORMED IN HIGH-VOLTAGE LABORATORY, APRIL 22, 1991

A Grove manlift device was positioned in the High-voltage laboratory under a 6.1 m (20 ft) section of high-voltage bus located 6.6 m (21.5 ft) above the floor. The overall height of the manlift was 2.6 m (8.5 ft) and the cage was in the lowered position with the top of the rail 5.2 m (17 ft) from the bus. The bus voltage for the tests was 318 kV, equivalent to a line-to-line voltage of 500 kV. There were no corona shields on the bus.

The Grove device has electrical circuit boards in a console located at rail height in the cage. No equipment manual was available, and it was not determined if the boards contained transistors or other solid-state components. Tests were performed with the console cover both open and closed. Tests were performed with the vehicle running and with the vehicle shut down.

The electric field produced by the overhead bus was measured. In addition, low frequency and high frequency voltages were measured on selected conductors at the engine-compartment control panel. The measurement points were, viewing from the front of the panel, (a) the lower right terminal of the LIFT UP/DOWN switch, and (b) the middle right terminal of the TELESCOPE IN/OUT switch. Electrical parameters were measured with the test equipment itemized in attachment B.

Observations:

(i) Fairly severe audible corona was produced by the overhead bus.

(ii) The 60-Hz electric fields produced by the overhead bus were 8 to 9 kV/m at a height of 1 m near the device, and were 15 to 16 kV/m at a height of 2 m. The difference is due in part to shielding provided by the device itself at the lower elevations.

(iii) The 60-Hz voltage at point (a) with the engine running and with the bus energised was 110 μV rms. The corresponding level at point (b) was 180 mV. Point (b) also showed about 1 mV of voltage at 51 Hz, apparently from the engine.

(iv) High frequency transients were observed at point (b) with the engine running or with the bus energised. The transients produced by the overhead bus (shown in Figure 1) were about 1 μs long and had an initial peak amplitude between 2 and 4 V. Transients produced by the engine (Figure 2) were 3 to 4 μs long but had a lower initial peak amplitude of about 1 V.

(v) No control malfunctions of the manlift device were observed.

3. TESTS PERFORMED AT KLEINBERG HIGH-VOLTAGE TEST SITE APRIL 24, 1991

The following tests were witnessed by representatives from the Ministry of Labour. A list of those present is provided in attachment C.

Two manlift devices were tested at the Kleinberg facility. Unit 1 was a "Simon", Ontario Hydro vehicle no. 396-109, and unit 2 was a JLG Lift model 46H displaying number 535. The units were positioned, in turn, parallel to a single overhead conductor located at a nominal height of 7.6 m (25 ft) with a horizontal separation of 4.6 m (15 ft) between the conductor and the nearest rail of the manlift platform. The overhead conductor was energised at 250 kV (equivalent to a line-to-line voltage of 400 kV) for some initial tests and at 318 kV for the remaining tests. Only the results for 318 kV are reported.

Unit 1 had hydraulic controls while unit 2 had electric and hydraulic controls. No equipment manuals were available, but neither unit appeared to have solid state control systems. Some tests were performed on unit 2 with the ground electrical control panel open. Both units were operated to raise and lower the platforms. Platform heights were measured to the top rail of the platform.

The 60-Hz electric and magnetic fields and the broadband electromagnetic radiation (assumed to arise from corona) at a horizontal distance of 4.6 m from the overhead line were measured. The transient electric field produced by line energization was also measured. In addition, the 60-Hz induced current on the unit grounding cable for various platform heights, and the 60-Hz

voltages and currents on selected conductors at the engine-compartment control panel of unit 2 for a platform height of 6 m (20 ft), were measured. The panel measurement points were the six terminals of the PLATFORM/GROUND control switch (see Figure 3).

Observations:

(i) The 60-Hz magnetic field level at the test site was less than 1 mG (0.1 μT) at all times.

(ii) The unperturbed 60-Hz electric field level at a height of 1 m was about 1 V/m (background), and increased to 8.5 kV/m with the conductor on potential. The machine itself shielded the electric fields to some degree, the amount of shielding increasing with increasing platform height. With the platform lowered, electric fields measured near the device on the far side from the energised line were 2 kV/m at a height of 1 m, and 6 kV/m at a height of 2 m.

(iii) Broadband electromagnetic fields at ground level, measured at 1 MHz, were nominally 600 μV/m/kHz. These field levels increased near the device, presumably due to a combination of engine emissions, and scattering and re-radiation.

(iv) The rise time of the energization surge was about 250 μs (Figure 4).

(v) The grounding current depended on the platform height. The measurements at 318 kV are shown in Table I.

(vi) 60-Hz voltages at the engine compartment control panel of unit 2 are shown in Table II. The two wires having significant voltages are thought to be floating, ie not connected to any ground reference. To confirm this, the short circuit current to ground at terminal A was measured. This current was 35 μA.

(vii) No control malfunctions of the manlift devices were observed.

4. SUMMARY

Three different manlift devices were operated at a nominal distance of 4.6 m (15 ft) from conductors energised to 318 kV, equivalent to a line-to-line voltage of 500 kV. The test conditions in each case were documented. No control malfunctions were observed.

Approved by:

F.Y. Chu
Supervising Engineer
Science Section

Submitted by:

S.M. Harvey
Senior Physicist
Science Section

TABLE I

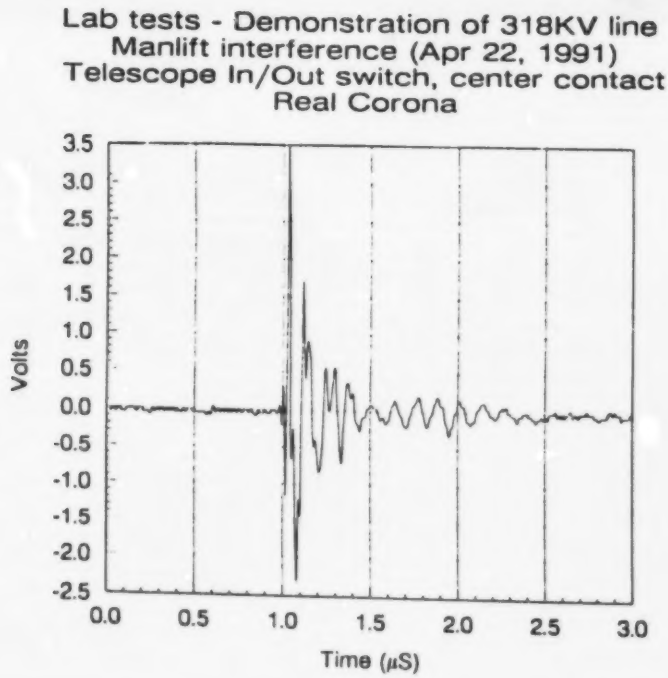
Grounding Current as a Function of platform height

platform height (m/ft)	unit 1 current (mA)	unit 2 current (mA)
lowered	1.6	1.8
3/10	-	2.4
6.1/20	3.4	3.5
9.1/30	4.6	4.1
12.2/40	6.0	5.4
15.2/50	6.2	-

TABLE II

60-Hz voltage on selected conductors at PLATFORM/GROUND switch

conductor (see Figure 4)	GROUND position (V)	PLATFORM position (V)
A	9.8	0.019
B	9.8	0.022
C	0.056	0.027
D	0.035	0.020
E	0.050	0.027
F	0.049	0.022



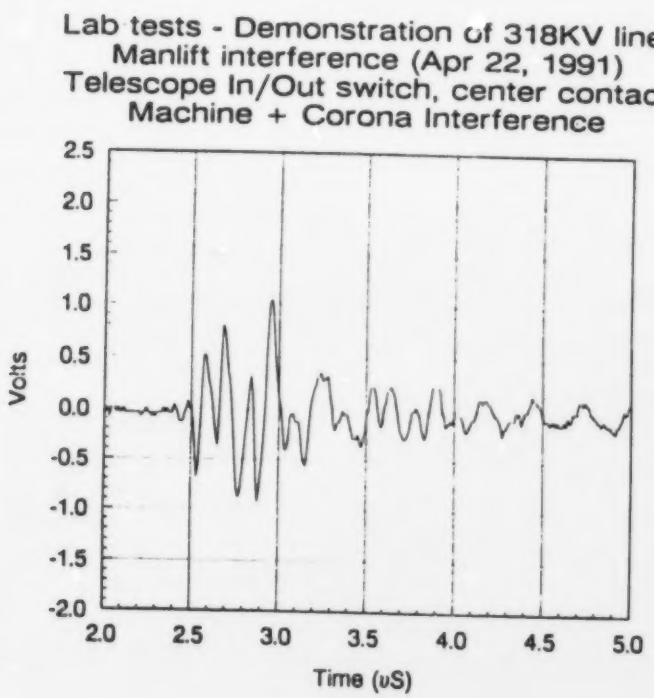
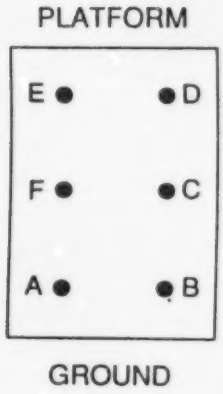


Figure 1 (Top). Transient voltage produced by Corona

Figure 2 (Bottom). Transient voltage produced by engine

Unit 2 switch terminals
viewed from front of panel



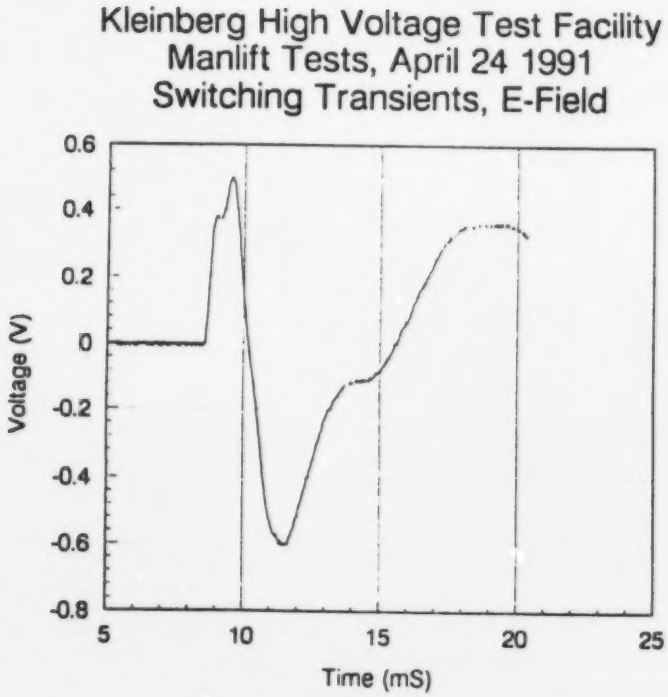


Figure 3 (Top). Identification of switch terminals

Figure 4 (Bottom). Transient field on line energization

ATTACHMENT A

Labour / Ministère du Travail de l'Ontario — Division / Division de la santé et de la sécurité au travail — Health and Safety Branch / Direction de la santé et de la sécurité dans la construction

Inspection Report / Rapport d'inspection

Project / Projet — 11. Report No. / Rapport : 79418

Name and Mailing Address of Constructor/Nom et adresse postale du constructeur

Ontario Hydro
700 University Ave.
Toronto, Ontario M5G 1X6

Address of Project/Adresse du projet — Tel. No./N° de téléphone

Ontario

Description of Project/Description du projet — Status/Situation

Construction

Name of Constructor or Employer Representative/Nom du représentant du constructeur ou de l'employeur

Directors of Ontario Hydro

Name of Owner/Nom du propriétaire

Ontario Hydro

Employer Name and Address/Nom et adresse de l'employeur

16. Inspection Date/Date d'inspection D/J	M/M	Y/A	32. Insp./Insp.	Div./Div.	Reg./Règl.	36. Activity/Activité	53. Work Force/Effectif	Contr./Avenant	58. Time In/Heure d'arrivée	45. Time Out/Heure de départ	47. Report a/Rapport n°	51.
02	04	91	663	16	02	100						

62. Report a/Rapport n°	67. Report a/Rapport n°	68. Report a/Rapport n°	69. Start Date/Date de commencement	73. Comp. Date/Date de parachèvement	75.	8 Value/Valeur $	First Aid/Premiers soins	No. of Pers./Nombre de pers.

Order under Section 28 of the Occupational Health and Safety Act, and Regulations Thereunder/Ordre donné en application de l'article 28 de la Loi sur la santé et la sécurité au travail et des règlements qui en découlent

To (Print Name and Address/A (Nom et adresse, en majuscules)

Directors and Officers of Ontario Hydro

18. C.S.B. o/N° CSC	21. Employer's W.C.B. o/N° C.A.T. de l'employeur	31. Alpha. Alpha	38.	Employer/ Employeur	Owner/ Propriétaire	Constructor/ Entrepreneur	Prime Contractor/ Entrepreneur principal	Supplier/ Fournisseur	Other/ Autre	Type/ Genre	39. Date/ Date d'émission
			1	2	3	4	5	6	7	8	

SR Div.	Act/Regulation/ Loi/Règlement	Section/Article				I Order You to Comply With the Sections Listed Below / Ordre vous est donné de vous conformer aux articles indiqués ci-dessous Location of Contravention(s) / Lieu de la (des) contravention(s)
43						
C	Reg.	1	0	5		Ontario Hydro shall ensure that all movable working platforms operated by mechanical
A	Act		1	9	a	or electrical power (including elevating rolling scaffolds and self propelled
						elevating scaffolds or work platforms) not specifically designed by the
						manufacturer for working in proximity to lines or equipment energized at more than 750 volts,
						are not brought closer than the minimum distances set out in Section 105(4) of
						R.R.O. 691/80, or the manufacturers instructions whichever is greater.
						Ontario Hydro Corporate safety rules are to be used only when the work is carried out using
						equipment which is adequate and specifically designed for the work being performed.
						Distribute orders to the Health and Safety representatives, committee members and
						post in a conspicuous place in the workplace.

Report Presented to (Name and Title)/Rapport présenté à (nom et fonction)

R.T. POPPLE DIRECTOR HEALTH + SAFETY

Signature of Recipient/Signature du destinataire

Inspector Data/Données de l'inspecteur

M. Brunner, C.H.S.O.
Ministry of Labour
C.H.S.B.
10 Milner Business Court,
Suite 404 Scarborough,
M1B 3C6

Signature of Inspector/Signature de l'inspecteur

16 OHS (9/83)

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Attachment B

Listing of Test Equipment

60-Hz Electric Fields:	Electric Field Measurement Co. model 120 field meter.
60-Hz Magnetic Fields:	Monitor Industries Inc. model 42A milligaussmeter.
60-Hz Voltage:	1:1 probe, with HP model 35660 network analyser.
60-Hz Current:	Pearson model 110 or 410 precision CT, with HP model 35660 network analyser.
Transient E-Field:	Home-build active broadband antenna with Tek model 2430 digital oscilloscope.
Transient Voltage:	1:1 probe with Tek model 2430 digital oscilloscope.
Corona:	Singer model NM25T EMI Field Strength meter with 41" rod antenna.

Attachment C

List of Participants at Kleinberg Tests, April 24, 1991

Ministry of Labour:	D. T. Mittelstaedt E. W. Mitchell H. B. Chan
Electrical Research Department:	E. A. Jones J. N. Edgar B. G. Kelk S. M. Harvey
Construction and Services Division:	R. A. Grunau
Lines, Stations & Hyd. Constr. Dept:	W. Bailey N. Hagan J. Bainard
Local 1788, IBEW:	W. Campsall

APPENDIX B

TESTS PERFORMED AT CHERRYWOOD TS, MAY 1 AND 2, 1991

The following tests were witnessed by representatives from the Ontario Ministry of Labour. A list of those present is provided in attachment D.

Two manlift devices were tested in the 500-kV switchyard at Cherrywood TS. Unit 1 was a "Simon" hydraulic, Ontario Hydro vehicle no. 396-112, and unit 2 was a "JLG" Lift model 60HA, Ontario Hydro vehicle no. 396-106, having electric over hydraulic controls. The units were positioned, in turn, parallel to C551V bus in a relatively open area adjacent to a roadway, as shown in Figure B1. The horizontal separation between the outside phase conductor, at a height of 7.9 m (26 ft), and the nearest rail of the manlift platform was set at 4.6 m (15 ft). The phase-to-phase voltage on the bus conductors was 518 kV (a line-to-ground voltage of 300 kV), and the load current was in the range from 475 to 500 A. The adjacent B542C bus was grounded at both ends during the tests.

Both units were operated to raise and lower the platforms. Platform heights were measured to the top rail of the platform. In addition, a contact test was performed with unit 1 at two locations along the grounded BB542C bus, by connecting the elevated platform to the outside phase through a short wire.

The 60-Hz electric and magnetic fields and the broadband electromagnetic radiation were measured at a horizontal distance of 4.6 m from the outside conductor of the V551V bus. The 60-Hz induced current on the unit grounding cable was also measured for various platform heights. In addition, voltages and currents were measured on the six terminals of the PLATFORM/GROUND selector switch of unit 2 with the platform at a height of 6 m, as was done at Kleinberg. A schematic of the "JLG" model 60HA electrical controls, obtained after the tests, was used to confirm that wires A and B from this switch were connected to the elevated platform. A simplified diagram of the switch circuit is shown in Figure B2.

Observations

(i) The 60-Hz magnetic field level at the test location was 100 mG (10μT).

(ii) The unperturbed 60-Hz electric field at the test location was about 7.5 kV/m, falling to between 5.5 and 6 kV/m near the J-bus support columns.

(iii) Broadband electromagnetic fields at ground level, measured at 1 MHz, were nominally 60 μV/m/kHz.

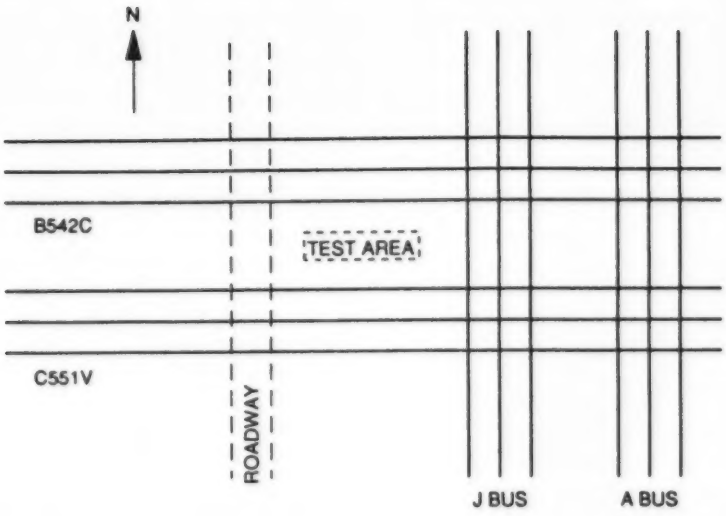
(iv) The 60-Hz grounding currents depended on the platform height. Measurements for the two units are shown in Table I of the main report.

(v) The 60-Hz grounding current produced by contact with the grounded bus was 10.2 A at a position near the test area, and 20.2 A at the midpoint of the B542C low bus. The resistance between the points of attachment to the bus and the station ground mat was between 0 and 0.1 ohms (the smallest digit on the DVM display). The voltage between the manlift platform in contact with the bus and the ground is therefore estimated not to exceed 2 V.

(vi) 60-Hz voltages at the ground level control panel of unit 2 are shown in Table II of the main report. The short circuit to ground current on terminal B was 190 μA, confirming the lack of ground reference on this conductor. There is some lack of consistency in these data. This is attributed to a faulty measurement procedure on some terminals (the tester hand-held the insulated probe wire to avoid shorting between terminals). Because of the high source impedance associated with electrostatically induced voltages, even a small amount of body capacitance or conductance is sufficient to lower the measured voltage significantly.

(vii) High frequency (transient) voltages on the switch terminals were very low, less than 5 mV.

(viii) No control malfunctions of the manlift devices were observed.



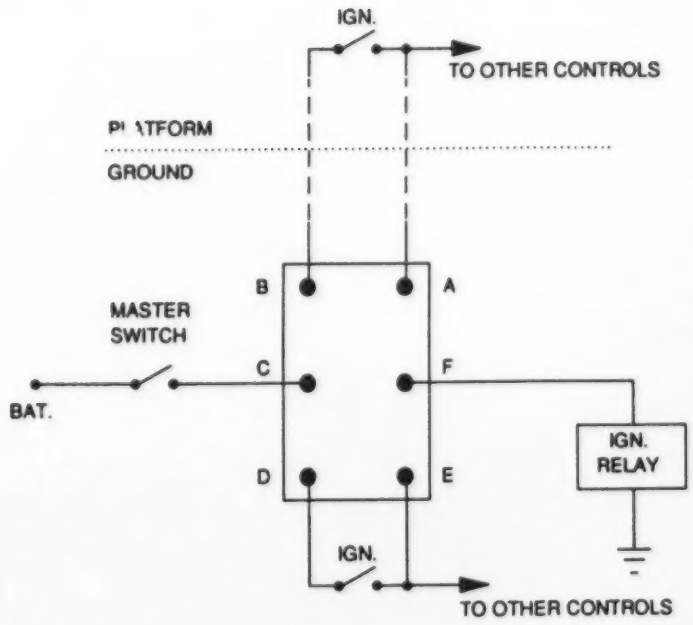


Figure B1 (Top). Location of Test Area

Figure B2 (Bottom). Simplified Schematic of Selector Switch

ATTACHMENT D

List of Participants at Cherrywood Tests; May 1 and 2, 1991

Ministry of Labour	D.T. Mittelstaed E.W. Mitchell H.B. Chan M. Brunner
Electrical Research	E.A. Jones S.M. Harvey R.R. Scheer
Lines, St. & Hyd. Constr. Dept.	D. Reid N. McCormack M. Enders
Cherrywood St. Maintenance	K. Sayers G. Isaacs N. Stevens R. Harrod
Local 1788, IBEW	W. Campsall J. Johnston J. Sprackett G. Chapman K. Kee R. Gilbert
L.W. Matthews Ltd.	P. Bissonette